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Impact of Broadband Quality on Median Income and Unemployment: Evidence from Sweden

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Impact of Broadband Quality on Median Income and Unemployment: Evidence from Sweden

Maude Hasbi*

Abstract

Based on a unique and exhaustive database, including micro-level cross-sectional data on 23 million observations over nine years, from 2009 to 2017, we assess whether broadband quality has an impact on income and unemployment reduction. Overall, the results do not show any significant effect of download speed on either income or the unemployment rate. However, after distinguishing between educational attainment and the city size, we obtained heterogeneous results. While we highlight a substitution effect between low-skilled workers and broadband in smaller cities, we also show that broadband quality has a positive impact on unemployment reduction for low-skilled workers in bigger cities. However, the model predicts a negative effect of broadband quality on both the median income and the unemployment rate in areas having a higher proportion of college graduates. This result tends to support the analyses showing that, with the progress made in machine learning, artificial intelligence and the increasing availability of big data, job computerization is expanding to the sphere of high-income cognitive jobs.

Key Words: *Broadband Quality, Fibre, Income, Unemployment, Artificial Intelligence.*

JEL Classification: L13, L50, L96

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2 Introduction

Very high-speed broadband networks are seen as a key enabler for socio-economic development. Their roll-out comes along with the development of advanced digital services in all areas of the society. As an example, the progresses made in artificial intelligence (AI) are opening doors to an unprecedented level of progress in health engineering and transportation. The digitalization of the society also creates benefits for the citizens. It gives them greater opportunities to participate in the civil society, to enjoy a broad range of services at home, such as welfare and healthcare services. In addition, job searches are facilitated increasing opportunities to find a work in lines with the person's competences. Digitization also creates opportunities for companies and entrepreneurship. It bridges geographical distances enabling more communication, exchanges and commerce. Thus, digitalization is considered important for the economy and for democracy.

Sweden, which is a sparsely populated country characterized by a long coastline with archipelagos, extensive forests and numerous lakes, is though one of the leading countries in terms of broadband deployment. Sweden has been particularly active in the roll-out of next generation broadband technologies, both fixed and mobile. The government is aiming for a completely connected Sweden, by 2025, with 98% of the population which should have access to broadband at a minimum speed of 1 Gbit/s both at home and at the workplace. The remaining 1.9% should have access to connections of at least 100 Mbit/s, and 0.1% at speeds of at least 30 Mbit/s. In addition, by 2023 everyone should have access to reliable and high-quality mobile services. The growth of mobile services is also dependent on the existence of a very high-speed broadband infrastructure connecting the base stations together.

To reach these ambitious targets, Sweden is not only relying on private initiatives but also on the commitment of the public sector. As a forerunner, Sweden launched its ambitious and interventionist national ICT infrastructure program already in 2000. In contrast with other European countries, which defined broadband as an Internet connection of at least 256 Kbit/s, Sweden had already then a more stringent definition including only transmission capacities of at least 2 Mbit/s in both directions. In line with this interventionist vision, local collectivities have traditionally played a significant role in the roll-out of broadband technologies, which has had an impact on the digitalization level of rural areas. Swedish municipalities lead the way to a competitive and well-functioning broadband market by being facilitators, landowners or active operators acting in the market in competition with private actors.

Sweden's high performances are far above the European average. The share of broadband connections of at least 100 Mbit/s is the second highest of the European Union. Besides, Sweden ranks second in the use of Internet services by households since 2017[1]. Given the recent deployment of next generation access networks (NGN), little empirical research has investigated the economic impact of very high-speed Internet on the society. Considering that Sweden is a frontrunner in very high-capacity connectivity in Europe, it is also a good candidate to assess the effects of broadband on socio-economics variables related to the households.

In this report, we quantify to which extent broadband quality, measured in terms of download speed, impacts income and unemployment in both urban and rural areas. This will enable us to investigate whether the roll-out of NGN networks is a way to answer the challenges encountered in the cities and in rural areas. More precisely, one challenge which is mostly encountered in rural areas and smaller cities is the lack of companies, which leads to a lack of jobs, a higher unemployment rate and a lower income, i.e. a lower purchasing power for households. Companies tend to locate in bigger cities where they can benefit from the local infrastructures, find their workforce, especially highly educated experts. In these areas, they can also find other companies which could potentially become their suppliers, clients, intermediaries. Another challenge is the depopulation of rural areas and smaller cities as those living in economically deprived areas may decide to relocate to areas with better job prospects. People tend to locate in areas where they can receive an education, find a workplace and benefit from the local infrastructures and the cultural structures. They have more chances to find a job in an area with more companies and especially to find a job they are interested in. Therefore, non-attractive areas may see their population decreasing and ageing; their cultural life and sociability places reducing; their public services being maintained to a minimum level and their grocery stores disappearing. As such the digital divide is also triggering the territorial and social divides.

These challenges could potentially be answered by the deployment of very high-speed broadband infrastructures. The possibility to work from home, to benefit from a reliable and sufficient internet connection to start a business could be a way to give a new life to non-attractive areas

[1]European Commission Digital Economy and Society Index (DESI 2017 - DESI 2018 - DESI 2019)

and help others to remain attractive. Some studies have also been showing that two otherwise similar urban areas could see their attractiveness impacted by the absence of very high-speed internet, especially in terms of attractiveness for companies (See for example McCoy et al. (2018) and Hasbi (2020)).

This study relies on a unique and rich dataset including 23 million measurement tests realized by Internet users all over Sweden. The tests have been performed using the "Bredbandskollen" test managed by the Swedish Internet Foundation. It provides us with micro-level cross-sectional data covering approximately 700 Swedish localities, located in 287 municipalities, over 9 years, from 2009 to 2017, giving us a wide coverage of Sweden.[2] The results highlight a positive effect of broadband quality on unemployment reduction in localities with a lower proportion of highly educated inhabitants. However, improvement in broadband quality is shown to have a detrimental effect on both the median income and the unemployment rate in localities with a higher proportion of highly educated inhabitants. In addition, the model highlights heterogeneous effects while taking into account the municipality size.

To the best of my knowledge, this is one of the first papers to estimate, at a granular local level in both urban and rural areas, the impact of very high-speed broadband network on socio-economic variables related to the demand, the median income and the unemployment rate. The results provide policy-makers with better insights on the role of very high-speed broadband for local economic growth and social development.

The remainder of the paper is organized as follows. Section 3 discusses the relevant literature on the effect of broadband on income and unemployment. Section 4 provides an overview of the state of the broadband market in Sweden. Section 5 presents the data. Section 6 introduces the econometric framework. Section 7 presents the estimation results. Finally, section 8 concludes.

3 Literature Review

As internet connectivity becomes ubiquitous and comprehensive datasets become available, many economists have tried to find answers to the 1987 Solow paradox: "you can see the computer

[2] A locality, DeSo in Swedish, is the smallest demographic and statistical area defined by the Swedish statistics institute. There are more than 5,000 DeSo in Sweden distributed in the 290 Swedish municipalities.

age everywhere but in the productivity statistics". In the last decade, an extensive range of macro-level studies bring empirical evidence on the positive effect of broadband adoption on economic growth (see Holt et al. (2009), Greenstein et al. (2011) and Bertschek et al. (2013) for comprehensive literature reviews). It is widely accepted that there is a positive relation between broadband adoption, broadband availability and economic growth, especially as measured by the GDP, at the national and regional level. A positive relation has also been found among others by Gillett et al. (2006), Crandall et al. (2007) and Ford et al. (2006), between broadband availability and employment at the macro-level. They find that communities with broadband experienced a more rapid growth in employment and a faster firm growth, especially in IT-intensive sectors than non-broadband communities.

Gruber et al. (2014) show that the economic benefits that would derive from the achievement of the objectives of the 2020 Digital Agenda for Europe outweigh the costs of investment. They show that the economic benefits mostly spill over to users and to the national economy highlighting the rationale for public subsidies in the roll-out of broadband networks. Another stream of literature has explored the relation between broadband and consumer surplus bringing positive evidence on the existence of a positive correlation. For example, Greenstein et al. (2012) point out that countries with large Internet economy have experienced increased consumer surplus because they simultaneously experienced large improvements in broadband quality and a decline in real prices.

The Great Recession of 2007-2009 has, however, led to challenge the common acceptance of the positive relationship between GDP and employment as digital technologies become more prevalent in all areas of the society. Analysing the situation in the US, Brynjolfsson et al. (2011) shed some light on the appearance of a weakening in this relation showing that, even though GDP is increasing in the US, there is no net employment creation. They highlight a decline in the quantity of labour demanded bringing back the 1800s concept of technological unemployment introduced in the economic theory by Ricardo and popularized by Keynes in the 1930s. *"This means unemployment due to our discovery of means of economising the use of* *labour outrunning the pace at which we can find new uses for labour"*, Keynes, 1930. [3]

The paradox of today is that we see everywhere that very high-speed broadband affects positively economic growth and social development at the local level, but the empirical evidences are very limited, divergent and ambiguous, especially as regards rural areas. A burgeoning literature has explored the relation between broadband and income. Whitacre et al. (2014) find that broadband adoption, availability and download speeds have an impact on economic growth in rural areas. They highlight a positive impact on unemployment reduction and on median household income. They also show that rural areas with high levels of download speeds tend to attract more creative class workers and to have a lower poverty level.

Autor et al. (2013) and Akerman et al. (2015) focus on job polarization and wage inequality. They show that broadband availability and adoption impacts positively the productivity of high-skilled workers, acting as a skill complement and lowers the productivity of unskilled workers, acting as a substitute for routine tasks. In 2009, Goos et al. observe a trend towards the polarization of the labour market between high-income cognitive jobs and low-income manual jobs leading to a hollowing-out of middle-income routine jobs. In addition, Autor et al. (2013) confirms the existence of a job polarization effect as low-skilled workers being specialized in routine tasks reallocate into the service sector.

Brynjolfsson et al. (2011) highlight that the polarization of the market between high-skilled and low-skilled workers leads to a stagnation of the median income with an increase in wage inequalities. Adding to that, Boland et al. (2015) show that broadband deployment in rural areas has stimulated wage increase and employment growth in the service industries, but not in the good industries. The complementary effect between broadband and high-skilled workers has also been highlighted by Hasbi (2020). She finds that on average areas covered by very high-speed broadband and having a high proportion of college graduates are more attractive for firms. However, and in line with the existence of a job polarization effect, she shows a higher positive effect of broadband on the creation of companies operating in the service sector in areas with a higher proportion of low-skilled workers.

[3] Technological unemployment is associated to what is considered a temporary phase of structural unemployment. It happens when, in a period of rapid technological change, the skills offered by the workforce don't evolve fast enough and become redundant leading to a capital-labour substitution.

Houngbonon et al. (2019) confirm the positive impact of broadband diffusion on poverty reduction highlighted by Whitacre et al. (2014). They find that high-speed broadband availability reduces income inequality in spite of skill complementarity. Besides, they point out the existence of a greater effect in less densely populated areas. This result is in line with Czernich et al. (2011), who find a positive impact of broadband infrastructure on the income per capita. Unlike Autor et al. (2013) and Akerman al al. (2015), Houngbonon et al. (2019) show that the impact is larger at the bottom of the income distribution.

As regards broadband effect on employment, Czernich (2011 and 2014) for German municipalities and Jayakar et al. (2013) for eight States in the US, find no evidence that broadband availability reduces unemployment. On the contrary, Kolko (2012) highlights that broadband expansion is associated with population growth and employment growth. However, he also finds that the average wage and the employment rate are unaffected by broadband expansion. Kolko underlines that the positive effects of broadband are stronger in industries that rely more on ICTs and in less densely populated areas. Atasoy (2013) confirms this result by showing that gaining access to broadband in a county is associated with an increase in the employment rate, especially in rural areas. She underlines also a complementary effect between broadband and skilled workers with college educated workers encountering larger effects. On the contrary, Canzian et al. (2015) find no impact on employment creation. But they find a positive effect of broadband diffusion on firm performance, especially in rural areas.

Using micro-level data for Bavaria from 2010 to 2014, Briglauer et al. (2019) evaluate the impact of a state aid program for broadband speeds upgrades in rural areas. They highlight the existence of a positive effect of broadband deployment on broadband coverage at higher speeds and on the reduction of depopulation in rural areas. However, they find no evidence of an impact on job creation. Comparing the economic impact of broadband and high-speed broadband on 8 States in the US for the years 2011-2014, Bai (2017) shows that even though broadband availability is positively correlated to county-level employment, fast broadband has no greater effect than "normal-broadband".

Building up on the advances realized in digital technologies, Frey et al. (2017) categorize jobs in accordance to their susceptibility to be computerized and analyse how computerization impacts the occupational composition of the labour market. They show that computer substitution does no longer only affect cognitive and manual routine tasks. With the progress made in areas such as machine learning, machine vision and artificial intelligence and with the availability of increasing amount of big data, non-routine tasks, such as legal writing, truck driving, medical diagnoses, some bank and financial services are becoming computerized. They highlight that 47% of total US employment is at high-risk of being computerized. Jobs that requires high dexterity, creativity or social intelligence are the least susceptible to be computerized. In addition, they show that wages and educational attainment are strongly negatively correlated with the probability of computerization. In a similar study for Sweden, Fölster (2014) shows that it is 53% of total employment, which is susceptible to be computerized within 20 years in Sweden. Brynjolfsson et al. (2011) argue that advances realized in what digital technology can do will inevitably continue increasing the number and types of jobs susceptible to be computerized.

The use of speed to measure the economic impacts of broadband is considered as more and more important in the literature. Middleton et al. (2013) argue that along with broadband penetration, speed and quality of service are also important determinants of the effects of broadband. In 2017, Rohman et al. reaffirm the importance to take into account broadband speed in the estimations and highlight the scarcity of academic research in this sense. Despite these observations, the effects of broadband speed on economic growth have been understudied. This could partially be explained by the lack of sufficient data.

4 Broadband Policy and Broadband Market in Sweden

4.1 Background on Broadband Roll-Out in Sweden

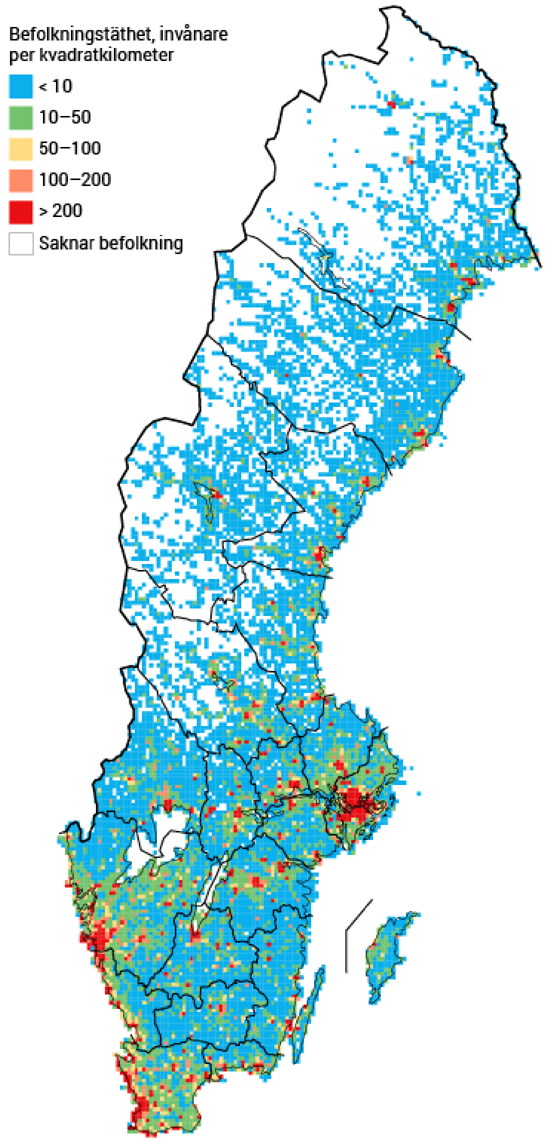
Very high-speed broadband should be accessible for everyone at the latest in 2025. This is the goal set by the Swedish government in its 2016 broadband strategy. More precisely, 98% of the population should have access to broadband at a minimum speed of 1 Gbit/s both at home and at the workplace. The remaining 1.9% of the population should have access to connections of at least 100 Mbit/s, and 0.1% at speeds of at least 30 Mbit/s. These ambitious targets should be put in context with the geographical reality of Sweden and its previous broadband strategies.

Sweden is a long and sparsely populated country with long coastlines and inhabited archipelagos. Forests cover 69% of the territory and only 3% of the land surface is inhabited. The population density is fairly low with small cities and villages scattered over the whole territory. In 2019, the average density of population was 25.4 inhabitants per square kilometre with big differences within the country[4]. 87% of the population lives in urban areas, mostly in the south of Sweden, principally in the three biggest cities: Stockholm, Gothenburg and Malmö[5]. Figure 1 provides an overview of the population density in Sweden. Sweden's geographic characteristics could be seen as a hinder for an extensive broadband coverage having a detrimental effect on the deployment costs of next generation broadband networks.

[4]As a matter of comparison, the density of population is of 432 inhabitants per square kilometre in England, 240 in Germany and 122.3 in France.

[5]There is about 10 million people living in Sweden, of which around 974,000 lives in Stockholm, 578,000 in Gothenburg and 339,000 in Malmö.

Figure 1: Population density in squares of five square kilometres.



Source: SCB report on population density in Sweden, updated in 2020.

This problem of sparsity is especially visible in rural areas where the potential number of customers reachable is lower[6].

[6]Sparsity is a recurrent problem in Nordic countries. It is defined ”as characterising regions where extremely low population densities and disperse settlement patterns create specific challenges for economic activity and public service provision”, see Gløersen et al. (2006)).

To reach the government's goals both the private and the public sectors work together. Sweden has a long tradition of public involvement in the deployment of broadband infrastructures. In 1999, Sweden was the first European country to define a national broadband strategy. In its vision of "an information society for all", the government emphases the importance of having a nationwide and reliable broadband infrastructure to ensure a healthy and well-functioning broadband market. Being a strategic infrastructure, it has been decided that it was the State which should bear the responsibility of its roll-out to ensure its availability throughout the whole territory. The broadband plan also provided a definition of broadband by including only transmission capacities of at least 2 Mbit/s in both directions, far above the European reference of 256 Kbit/s. The plan contained two main strategies.

The first one consisted in restricting Telia's monopoly position, the incumbent operator, by opening-up its network by the mean of local loop unbundling (LLU). LLU is a regulatory tool enabling alternative broadband operators to provide their services by using the network of the incumbent. Therefore, they do not need to deploy first their own infrastructure. LLU is a tool to ensure service-based competition (in opposition to infrastructure-based competition) and to create sustainable competition in the provision of broadband services that should then lead to lower prices for municipal residents. The second main strategy was to provide government funding of 4,150 million Swedish crowns (approximately 400 million Euro) to promote infrastructure deployment between 2000 and 2005. These funds were allocated to three different levels of network hierarchy: the backbone networks, the regional and local networks. The public investment in the base network aimed at building a competitive national backbone to Telia's network. The municipal networks build at the regional and local levels were open and operator-neutral. Municipal as well as private operators could provide broadband services to the end-users. The national broadband strategy resulted in the availability of a nationwide broadband network, with 99% of households having access to a DSL connection.

In Sweden, municipalities can promote competition in the broadband area in different ways: (1) by promoting the expansion of broadband networks; (2) by providing support in land planning and (3) by investing in network deployment. Municipalities involvement in broadband deployment is a way to meet the broadband targets defined by the government. Their role is to ensure that everyone gets access to the broadband infrastructure. This means that they are responsible for the definition of local broadband strategies and have at their disposal a broad range of tools. They can be a facilitator by easing the administrative processes, for example by making it easier to get specific authorizations. They can also be a landowner or play the role of a coordinator between different actors. They can also be a financial partner or the main investor. A municipality can also be an active operator acting in the market in competition with private actors. To ensure the realization of the government strategy and frame competition in the broadband market, municipalities rely on the deployment or upgrade of different technologies, often in combination, such as optical fibre, copper upgrade with xDSL technologies, cable upgrade, wireless technology, mobile broadband or satellite.

The strategies defined by the municipalities are based upon their specific characteristics and differ from one another. Some of them results from a municipal vision, some others are the product of civil initiatives. The need for broadband deployment can stem from a public consultation or from the civil society.[7] High-speed broadband is seen as a tool to preserve a dynamic economy and counteract the depopulation movement. In all cases, before public funding are granted, municipalities must first define a broadband project that is then submitted to the regional county administrative board for approval[8].

Funding can be delivered to any legal person who intend to build a broadband network for more than just its own needs or its own business. Therefore, all types of associations, organizations, companies, municipalities and other authorities can receive financial support. Public funding is only directed towards the roll-out of broadband networks that meet the definition of a next generation access network, i.e. broadband networks with high transmission capacity that are of very high-speed, reliable and with symmetric signal transmission. Fibre optical networks are eligible to receive support, along with upgraded copper networks via VDSL, upgraded cable networks: DOCSIS 3.0 or wireless networks (under certain conditions). Other technologies could be eligible if it is possible to justify that they meet the requirements for NGA networks. In line with the European and national regulation, a prerequisite for a project to be eligible for

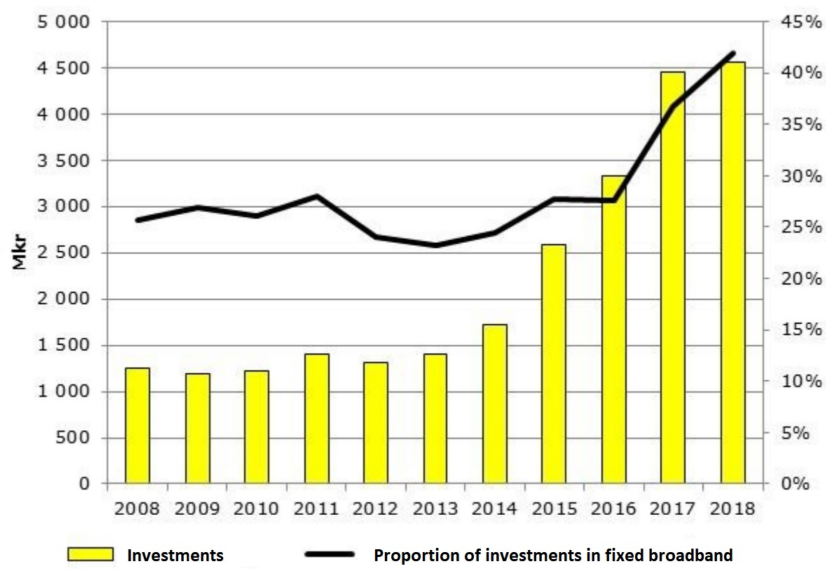
[7] In some remote areas, the need for broadband can indeed be raised by the local population or companies.

[8] A county administrative board (in Swedish länsstyrelse) is a regional government Agency. There are 21 of them, one in each of the counties of Sweden.

broadband funding is the existence of a market failure, i.e. the lack of private initiative. When a municipality builds a municipal network, the national regulator PTS recommends that the municipality grants passive access to the network by the use of dark fibre. The solution of an open net is a way to increase the customer's choice of an Internet service provider and enables more innovations.[9]

There are more than 200 municipal networks in Sweden. Figure 2 provides an overview of the amount of municipal broadband investments under a period of 10 years, from 2008 to 2018. While figure 3 shows the total amount of investment in broadband infrastructure during the same time period.

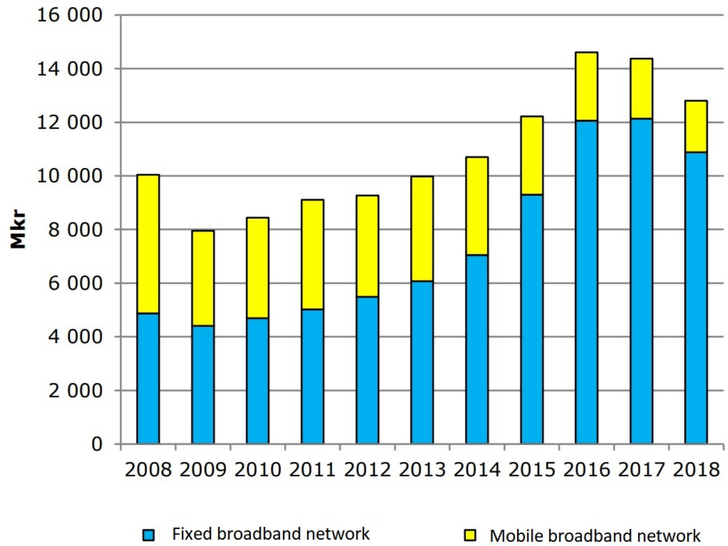
Figure 2: Municipal broadband investments from 2008 to 2018.



Source: PTS report 2019 "Investeringar och förutsättningar för bredbandsutbyggnad Delrapport av Uppföljning av regeringens bredbandsstrategi 2019".

[9]The network should be made available in open access to any operator and with non-discriminatory conditions.

Figure 3: Total investment in broadband infrastructures from 2008 to 2018.



Source: PTS report 2019 ”Investeringar och förutsättningar för bredbandsutbyggnad Delrapport av Uppföljning av regeringens bredbandsstrategi 2019”.

4.2 Broadband market in Sweden

Sweden is one of the most connected country in the EU. In 2008, the first year in the dataset, broadband penetration in Sweden was already high, exceeding by far the European average. The proportion of households with internet access was of 84%, the second highest of the EU27. It increased to 92% in 2012 and to 95% in 2018. In comparison, on average in the EU27, only 59% of households had internet access in 2008. This proportion grew to 75% in 2012 and to 88% in 2018.

In addition, of a high broadband penetration, Sweden ranked third, after the Netherlands and Denmark as regards broadband adoption. In 2008, 71% of the Swedish households (respectively 46% of EU27 households) had a broadband connection. In 2018, they were 93%. This also means that almost every household having an internet connection subscribed to a broadband offer. In comparison, the number of EU households having a broadband connection in 2018 was

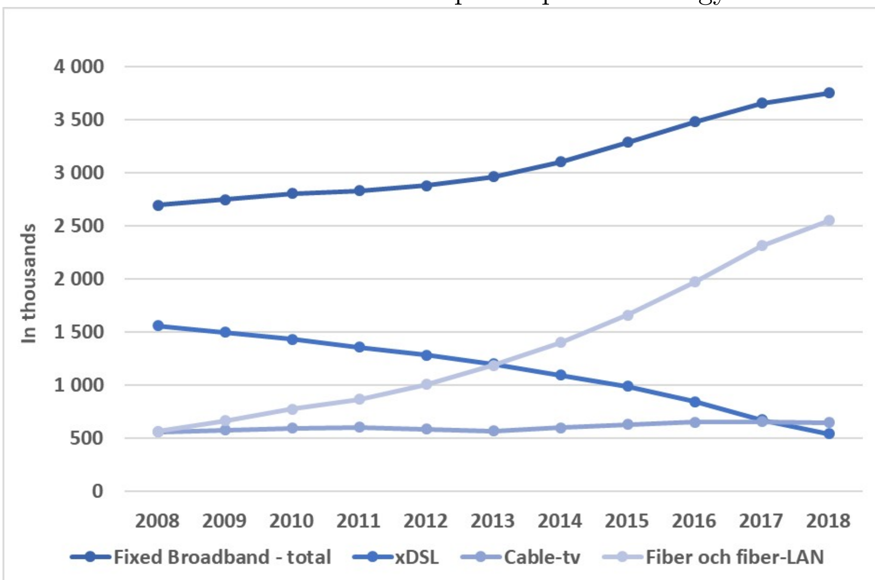
8 percentage points lower.[10]

There are three main operators active in the Swedish fixed broadband market: Telia Company, Telenor and Tele2. Telia Company is the incumbent operator. Its market share in the fixed broadband market has been fluctuating from around 38% to 35% from 2008 to 2018. Its principal competitor, Telenor, provides roughly one fifth of the broadband subscriptions in the market (from roughly 22% in 2008 to 18% in 2018) while Tele2 was a smaller player in 2008 with around 10% of the market, its market share doubled in 2018 to a bit more than 20%. Bahnhof and Bredband2 are two smaller competitors active in the provision of fibre services. In 2018, the three largest operators, Telia Company, Telenor and Tele2 (after the merger with Com Hem) accounted for over 72% of the broadband subscriptions.

In Sweden, as in most European countries, four main wire-line technologies are used to deliver high-speed broadband connections: digital subscriber line (DSL), very-high-bit-rate digital subscriber line (VDSL)[11], cable modem, of which DOCSIS 3.0 (DOCSIS 3.0 is a cable upgrade standard, which enables the provision of very high-speed broadband services to the end-users) and optical fibre. Figure 4 shows the evolution of fixed broadband subscriptions per technology between 2008 and 2018.

[10] source: All the statistics come from Eurostat.
[11] VDSL is a DSL technology providing faster transmission speeds than standard DSL for short copper lines.

Figure 4: Number fixed broadband subscriptions per technology from 2008 to 2018.



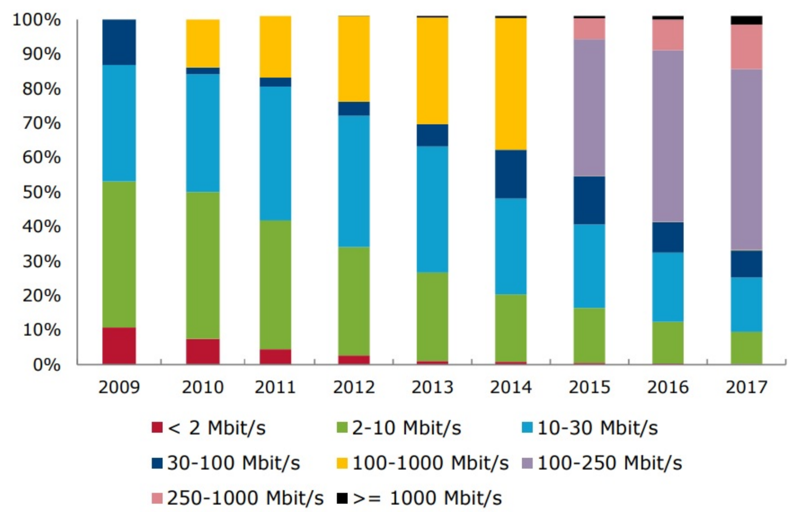
Source: PTS report 2019 "The Swedish Telecommunications Market 2018".

While Internet subscriptions via xDSL (ADSL and VDSL) technologies and especially ADSL were predominant until 2011, their number started to decrease steadily from 2012. On the contrary, broadband connections provided via next generation access network, such as upgraded cable and fibre, have been increasing. However, broadband subscriptions via cable have increased in a smaller pace and started decreasing in 2018. This is due to the limited footprint of the cable network. Around 37% of households and 27% of workplaces have access to the cable network. The cable network footprint has been stable over time, whereas the fibre network coverage has increased. In 2008, around 35% of households and 32% of workplaces had access to fibre. Ten years later, in 2018, the fibre network had reached around 77% of households and 73% of workplaces. Since 2010, fibre (including fibre LAN) has accounted for most of the growth of fixed broadband subscriptions.

According to PTS, the Swedish regulator, between 2013 and 2018, the share of households having access to high-speed broadband of at least 30 Mbit/s and at least 100 Mbit/s has been evolving quite fast. In 2013, 72.6% of the Swedish households had access to at least 30 Mbit/s connections, there were almost 54% having a broadband connection of at least 100 Mbit/s. In 2015, the share of households having access to at least 30 Mbit/s connections increased to more than 88% and to almost 97% in 2018. While the share of households having access to at least 100 Mbit/s connections increased to almost 67% in 2015 and to approximately 82% in 2018.

Figure 5 provides an overview of the distribution of fixed broadband subscriptions by speed between 2009 and 2017.

Figure 5: Proportion of fixed broadband subscriptions by speed from 2009 to 2017.



Source: PTS report 2019 "The Swedish Telecommunications Market reports 2016-2019".

5 Data

Data on broadband speed comes from Internetstiftelsen. The Swedish Internet Foundation, Internetstiftelsen, is an independent organization that works for the development and improvement of the internet in Sweden. One of the main focus is to raise end-users' awareness and knowledge about the Internet. To that purpose Internetstiftelsen is managing an online tool called Bredbandskollen aiming at measuring access connection speed. This tool is free of use and allows everyone across the country to test its internet connection in terms of download and upload speed in Mbit/s and latency in seconds. We got a dataset with broadband measurements over 9 years, from 2009 to 2017. These data have been collected at an established aggregation level in Sweden (tätort). Tätort is defined as urban areas with contiguous buildings with no more than 200 metres between houses and at least 200 residents. There are around 2,000 tätorter in Sweden comprising around 87% of the population.

Using a dataset on broadband speed instead of on the type of Internet technologies has a number of potential benefits. First, the importance of taking into account Internet speed to measure the impact of broadband on different socio-economic variables has been highlighted in the literature. With these data, we have information on the demand and therefore, on the actual Internet access speed of the households. This gives us an overview of the network quality and enables us to avoid biases related to the different physical characteristics of a technology. For example, the connection speed on a DSL line is dependent on the line length. Longer is the line, lower is the speed. As such, for the same technology, the broadband speed experienced by the end user can vary significantly. In addition, it avoids biases related to the use of the theoretical speed marketed by the operators, which is the maximal theoretical speed reachable under specific circumstances and not necessarily the actual speed experienced by the customers.

However, the dataset includes some sort of positive self-selection in which the user expresses an interest and demand in order to use the measurement test (Bredbandskollen). There are two main reasons to test an Internet connection. The first one is that the user is experiencing a problem, such as a slow download or upload speed or a high latency. To correct this bias, all observations with abnormally long latency or very slow download speed or upload speed are dropped out. The second main reason to use the test is when an Internet user has changed his or her subscription. However, because these behaviours repeat every year, it is reasonable to consider that it doesn't introduce a bias in the data. There will be each year tests on new (and most probably faster) Internet subscriptions. All in all, because it is the user expressing an interest in testing its Internet connection, our data is closer related to expressed demand rather than supply.

Finally, the data set is very extensive. Over the 9 years, the number of actual tests conducted through Bredbandskollen amounts to more than 300 million use cases, of which a third had usable location coordinates. After dropping observations related to unrealistic broadband speeds or latencies, only data on tests performed the second week of each month have been kept. The estimations have been performed on a representative sample of 23 million observations (tests). Considering the large number of measurements, we get a wide coverage of Sweden.

Data on unemployment and income come from the Swedish statistical agency, SCB. The data on unemployment represents the number of openly unemployed aged 18 to 64 registered as job seekers. Data on income from employment and business are available for the population aged 20 and over.

Finally, socio-demographic data on population, population density, country of birth, age groups, education level and number of new and reactivated companies come from SCB. As the geographical level of the data from Bredbandskollen are different from the socio-economic data received from SCB, we used a connection table between DeSo and tätort provided by SCB. (The so-called DeSo level of SCB is the smallest aggregation level provided by SCB.) Descriptive statistics are reported in Annex A in tables 8 to 10.

6 Econometric Strategy

How broadband can impact unemployment is still arguable. The relationship between broadband and unemployment has been shown to be ambiguous. The digitalization of companies has had an impact on the way goods are produced and delivered through the introduction of more automated processes. As such, the deployment of broadband and especially very high-speed broadband has had a double effect. On the one hand, the use of more efficient technologies has led to productivity gains and an increase in economic growth. These would suggest a positive effect on employment. On the other hand, the use of more efficient technology had potentially substituted for labour, especially within the low-skilled workforce, suggesting a negative impact on unemployment. On the other hand, the demand for labour with specific skills has potentially increased, counterbalancing the substitution effect for more routine tasks.

The relation between broadband and income is not straightforward either. The skill complementarity between broadband and high-skilled workforce leads to an increase in income inequality. While the growth of low-skilled jobs in the service sector, resulting from the diffusion on new ICT technologies, is likely to have a positive impact on income.

The empirical strategy consists in investigating the effect of broadband quality on both the median income and the unemployment rate. Broadband quality is measured in terms of download speed. The use of broadband speed instead of the presence of a broadband network or the type of broadband technology deployed gives a more accurate information and provides more details on specific areas (Kongaut et al. (2017)). The empirical strategy consists in a stratification of broadband speed in 7 categories:

- No broadband: 0 to 256 Kbit/s;
- Low speed: over 256 Kbit/s to 5 Mbit/s;
- Medium speed: over 5 Mbit/s to 10 Mbit/s;
- Medium speed 2: over 10 Mbit/s to 30 Mbit/s;
- High-speed: over 30 Mbit/s to 50 Mbit/s;
- High-speed 2: over 50 Mbit/s to 100 Mbit/s;
- Very high-speed: over 100 Mbit/s.

To estimate the effect of broadband speed on (1) the median income and (2) the unemployment rate, we use data on 696 localities, (corresponding to 1,217 DeSo spread over 281 municipalities[12]) over 9 years, from 2009 to 2017. Only localities located in an urban settlement of at least 200 inhabitants (tätort) are included in the database.

So we have,

$$Y_{it} = \alpha + \delta \; hbb_{it-1} + \beta \; X_{it-1} + \gamma \; Z_{it-1} + \mu \; year_t + \eta_i + \epsilon_{it}. \tag{1}$$

In model (1) Y_{it} refers to the median income whereas in model (2) Y_{it} refers to the unemployment rate, both in locality i at time t. The variable of interest, denoted hbb_{it-1}, is a proxy for broadband quality in locality i at time $t-1$. Broadband quality is approximated by broadband speed, which is measured by the download speed in Mbit/s. X_{it-1} is a matrix of location characteristics for locality i at time $t-1$. Z_{it-1} is a matrix of labour market characteristics for locality i at time $t-1$. η_i controls for regions-specific trends that are constant over time. $year_t$ is a set

[12]DeSo is the smallest administrative division in Sweden. Socio-economic-data are provided at the DeSo level.

of dummy variables for each year that controls for years-specific effects that are constant over the different geographical areas. Finally, ϵ_{it} is a standard error capturing unobserved factors.

As highlighted in the literature, there is a potential endogenous effect, materializing in terms of reverse causality, between the availability of broadband networks and broadband quality and the median income, see, for example, Kolko (2012), Mack et al. (2011) and McCoy et al. (2018). In other words, operators are more likely to upgrade network quality or deploy a next generation access network in areas with a higher quality of demand. In the meantime, areas with better broadband infrastructures are more likely to attract households with a higher income.

As argued by Lobo et al. (2020), the use of lagged explanatory variables is a common approach in the literature to mitigate problems related to endogeneity in the social science. Following the literature, I control for pre-existing location characteristics and pre-existing labour market characteristics by using one-year lagged variables. Robustness checks are performed with lags of 1 year and 3 years, which give similar qualitative results. Nevertheless, one can suspect that the estimation results might suffer from an upward bias.

Omitted variables may also be a potential source of endogeneity. For example, operators may have higher incentives to deploy a very high-speed broadband network or upgrade network quality in areas in which they can benefit from a more favourable tax regime or in which there is higher demand for faster broadband services. To mitigate this problem, I follow the econometric literature by using time-varying and time invariant fixed effects.

Using (1), the median income can be derived:

$$\begin{aligned} income_{it} = \ & \alpha + \ \delta \ hbb_{it-1} + \beta_1 \ ln\_pop_{it-1} + \ \beta_2 \ ln\_pop\_m_{jit-1} \\ & + \beta_3 \ density_{it-1} + \ \beta_4 \ non\_EU_{it-1} + \gamma_1 \ unempl_{it-1} + \ \gamma_2 \ ln\_uni\_diploma_{it-1} \\ & + \gamma_3 establishment_{it-1} + \ \mu \ year_t + \ \eta_i + \ \epsilon_{it}, \end{aligned} \tag{2}$$

With $income_{it}$ the yearly income from employment and business in locality i at time t, which is expected to be influenced by broadband quality hbb_{it-1}, by the locality size, i.e. local population denoted by ln_pop_{it-1} and population density $density_{it-1}$.[13] The unemployment rate, $unempl_{it-1}$, is also likely to impact the median income as well as the education level of the population, measured by the proportion of the population having a diploma from superior education, $ln\_uni\_diploma_{it-1}$. It has also been shown for the US (Lobo et al. (2020)), that areas with a higher proportion of non-whites are more likely to experience a higher unemployment rate. This potential impact is captured by non_EU_{it-1}, which measures the proportion of inhabitants born outside Scandinavia and outside the European Union. In addition, the model includes information on the number of new establishments $establishment_{it-1}$ operating in the locality. All socio-demographic variables are estimated in locality i at time $t-1$. One variable is measured at a different geographical level, as the model includes information on the population of the municipality to which the locality belongs, denoted by $ln\_pop\_m_{jit-1}$.

Using (1), the unemployment rate could be derived as follows:

$$\begin{aligned} unempl_{it} = \; & \alpha + \; \delta \; hbb_{it-1} + \; \beta_1 \; ln\_pop_{it-1} + \; \beta_2 \; ln\_pop\_m_{jit-1} + \; \beta_3 \; density_{it-1} \\ & + \beta_4 \; ln\_income_{it-1} + \; \beta_5 \; non\_EU_{it-1} + \; \gamma_1 \; ln\_uni\_diploma_{it-1} \\ & + \gamma_2 establishment_{it-1} + \; \mu \; year_t + \; \eta_i + \; \epsilon_{it}, \end{aligned} \tag{3}$$

With $unempl_{it}$, the number of openly unemployed aged 18 to 64 registered as job seekers in locality i at time t, defined as a function of broadband quality, the local and municipal population, the local population density, the proportion of inhabitants born outside Scandinavia and outside the EU, the educational level, the number of new establishments. In addition, the yearly income, ln_income_{it-1}, is expected to influence the unemployment rate.

It has been shown in the literature that some benefits of broadband were found to be complementary with high-skilled labour forces and highly educated inhabitants (Akerman et al. (2015) and Hasbi (2020)). To assess whether broadband quality affects differently areas with (1) a higher, (2) a lower proportion of highly educated inhabitants, an alternative specification to 1

[13] The estimations have been run using the median income in real terms, i.e. deflated by the consumer price index. The results were qualitatively similar in terms of significance. This is explained by the use of year-fixed effects that capture the evolution of the consumer price index over the years.

taking into account educational attainment is defined.

$$\begin{aligned} Y_{it} = \ & \alpha + \ \delta_1 \ hbb_{it-1} + (\ \delta_2 \ hbb_{it-1}. \ high\_skilled_{it-1}) \\ & + \beta \ X_{it-1} + \ \gamma \ Z_{it-1} + \mu \ year_t + \ \eta_i + \ \epsilon_{it}. \end{aligned} \tag{4}$$

With $high\_skilled_{it-1}$ taking two values: 1 if the proportion of inhabitants having obtained a diploma from superior education is higher than the median and 0 otherwise.

The potential effects of broadband may also differ across municipality size. Political decisions are not made at the DeSo level but at a higher administrative level, such as the region or the city. Cities of different sizes have also different budgets or possibilities to grow and develop. This is why, it is important to compare localities belonging to the same type of cities. In our database, 50 % of the population lives in municipalities with less than 135,500 inhabitants, while 10% lives in municipalities with less than 19,000 inhabitants or more than 920,600 inhabitants.

Table 1: Population distribution in municipalities and DeSo.

	p1	p5	p10	p25	p50	p75	p90	mean
municipality	5,552	10,748	18,937	44,813	132,536	844,838	920,608	354,349
DeSo	936	1,128	1,282	1,492	1,606	1,954	2,292	1,712

To analyse whether the effects of broadband quality materialize differently depending on the municipality size, another specification is defined:

$$\begin{aligned} Y_{it} = \ & \alpha + \ \delta_1 \ hbb_{it-1} + (\ \delta_2 \ hbb_{it-1}. \ municipality\_size_{jit-1}) \\ & + \beta \ X_{it-1} + \ \gamma \ Z_{it-1} + \mu \ year_t + \ \eta_i + \ \epsilon_{it}. \end{aligned} \tag{5}$$

with $municipality\_size_{jit}$ the size of municipality j, to which locality i belongs, at time $t-1$, which can take 5 values:

- municipalities with a number of inhabitants equal or lower than 18,937 inhabitants (rank 1);
- municipalities with a number of inhabitants comprised between 18,938 and 44,813 (rank 2);
- municipalities with a number of inhabitants comprised between 44,814 and 132,536 (rank 3);
- municipalities with a number of inhabitants comprised between 132,537 and 354,349 (rank 4);
- municipalities with more than 354,349 inhabitants (rank 5).

7 Impacts of Broadband Quality on the Society

In this section are presented both the estimation results for the impact of broadband quality on income (6.1) and on unemployment (6.2). Only the results on the impact of download speed are presented here. The exhaustive estimation results are displayed in Annex B, tables 12 to 17.

Tables 2, 3 and 4 show the estimation results of the impact of broadband quality, in terms of download speed, on the yearly median income. Tables 5, 6 and 7 display the estimation results of the impact of broadband quality on the unemployment rate for the 18-64 years old.

The estimations are performed at the locality level for the years 2009 to 2017. As the effects of broadband may not be equally distributed into the society and instead may depend on (1) the educational level of the population or (2) the degree of urbanization of the area, the estimations have been run on seven sub-samples. Tables 3 and 6 (high skilled) shows the estimation results for localities having a high-skilled population, i.e. the proportion of inhabitants having obtained a diploma from superior education is higher than the median. While tables 4 and 7, (low skilled), displays the estimation results for localities having a low-skilled population, i.e. the proportion of inhabitants having obtained a diploma from superior education is lower than the median.

The database is further divided in 5 sub-samples (ranks 1 to 5) based on the size of the city to which the locality belongs. Therefore, it enables us to make within-group estimations and see how broadband quality affects income and unemployment within a group. Column 1 of each table presents the estimation results for the whole sample and column 2 for localities located in smaller municipalities of rank 1. Columns 3 and 4 shows the results for localities located in medium-sized municipalities of ranks 2 and 3 respectively. Column 5 presents the results for localities located in bigger cities of rank 4. In addition, tables 4 and 7 column 6 shows the results for localities located in the biggest cities, those having a population higher than the average: rank 5.

7.1 Impacts of Broadband Quality on Income

The exhaustive estimation results are displayed in Annex B in tables 12 to 14.

Table 2 do not show any significant effect of broadband quality on median income. This result holds irrespective of the size of the city to which the locality belongs. Therefore, we cannot conclude that broadband quality has an impact on income.

Table 2: Impact of broadband quality on median income.

	whole sample	rank 1	rank 2	rank 3	rank 4	rank 5
speed: 0.256-5						
speed: 5-10						
speed: 10-30						
speed: 30-50						
speed: 50-100						
speed: 100+						
Observations	31,472,261	3,525,546	5,214,661	8,125,111	3,542,502	11,065,066
R-squared	0.898	0.691	0.837	0.908	0.986	0.996
Region	Yes	Yes	Yes	Yes	Yes	Yes
Year	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.898	0.691	0.837	0.908	0.986	0.996

Robust standard errors clustered at the DeSo level: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$
rank 1: pop $\leq$ 18,937; rank 2: pop [19,938 - 44,813]; rank 3: pop [44,814 - 132,536];
rank 4: pop [132,537 - 354,349].
A blank case means no significant effect.

The results, displayed in table 12, highlight that the median income is more likely to be higher in more populated localities as well as in localities with a lower unemployment rate. Nevertheless, we also notice that more densely populated localities as well as localities in which the proportion of inhabitants born outside Scandinavia or outside the EU is high, are more likely to have a lower median income. In line with the literature, the results show a positive effect of educational attainment on income. The median income is more likely to be higher in localities having a higher proportion of college graduates.

High-skilled Localities

The second part of the results concerns localities characterized by a high proportion of highly educated inhabitants. Overall, the model predicts a negative effect from broadband on the median income of high-skilled workers. However, after distinguishing between the different municipality sizes, this result holds only for localities belonging to a medium-sized municipality. Otherwise, in smaller medium-sized municipalities broadband quality is found to have a positive impact on the income of high-skilled workers.

More specifically, the first column of table 3 reveals a negative impact of broadband quality on median income for high-speed and very high-speed broadband (speeds over 30 Mbit/s and especially over 100 Mbit/s). The results show that the negative impact of broadband quality increases with download speed. On average, the median yearly income in localities with high-speed broadband (between 30 and 50 Mbit/s) is 430 Swedish crowns (about 43 euro) lower than in localities without broadband. This difference in median income increases to 1,060 Swedish crowns (about 106 euro) in localities with very high-speed broadband (speed over 100 Mbit/s).

However, this result hides differences depending on the size of the city to which the locality belongs. In that respect, column 2 shows that there is no significant impact of broadband quality on income in localities located in smaller cities (with less than 18,937 inhabitants). A positive effect, increasing with download speeds, is found in localities located in a medium-sized city (rank 2). In localities with broadband speed comprised between 5 and 30 Mbit/s, the yearly median income is approximately 2000 Swedish crowns (about 200 euro) higher than in other localities of rank 2 without broadband. In localities with high-speed broadband (between 30 and 100 Mbit/s), the yearly income is about 3,000 Swedish crowns (about 300 euro) higher compare to other localities of rank 2 without broadband. However, there is no significant effect of basic broadband (between 256 Kbit/s and 5 Mbit/s) or very high-speed broadband (over 100 Mbit/s) on median income.

Similarly, column 5 shows that localities located in bigger cities (rank 4) that have a low broadband quality (under 5 Mbit/s) are more likely to have a slightly higher yearly median income than other localities of the same rank without broadband: 138 Swedish crowns (about 14 euro) more per year. However, localities located in areas with higher broadband speed do not encounter any significant impact of a higher broadband quality.

In accordance with the general picture, localities located in larger medium-sized cities of rank 3 are more likely to encounter a negative impact of broadband quality on median income: higher are the download speeds, lower is the median income. On average, the median yearly income in localities with broadband speed between 5 Mbit/s and 50 Mbit/s is of about 1000 Swedish crowns (about 100 euro) lower compare to localities of rank 3 without broadband. This difference increases to around 1200 Swedish crowns (about 120 euro) in localities with very high-speed broadband (over 100 Mbit/s). A bit less than a third of the localities are located in a municipality of rank 3. This explains the general negative effect found for the estimation of the whole sample.[14]

[14] The municipal population is added as a control but does not have a significant impact on the median income.

Table 3: Impact of broadband quality on income in localities characterized by a high proportion of highly educated inhabitants.

	whole sample	rank 1	rank 2	rank 3	rank 4
speed: 0.256-5					138.15*
speed: 5-10			1,922.03**	-979.5*	
speed: 10-30			2,129.65**	-1,016.11**	
speed: 30-50	-430.17*		3,231.26***	-946.02**	
speed: 50-100	-611.27**		2,975.89***	-1,165.54**	
speed: 100+	-1,060.57**			-1,282.73**	
Observations	15,741,382	1,762,937	2,607,396	4,032,688	1,754,337
region	Yes	Yes	Yes	Yes	Yes
year	Yes	Yes	Yes	Yes	Yes
R-squared	0.926	0.640	0.736	0.947	0.991

Robust standard errors clustered at the DeSo level: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$
rank 1: pop $\leq$ 18,937; rank 2: pop [19,938 - 44,813]; rank 3: pop [44,814 - 132,536];
rank 4: pop [132,537 - 354,349].
A blank case means no significant effect.

Low-skilled Localities

The third part of the results concerns localities characterized by a low proportion of highly educated inhabitants (inferior to the median). All in all, the model doesn't predict any effect of broadband quality on the income of low-skilled workers. However, after taking into account the city size, the model shows a negative effect of broadband on the income of low-skilled workers in smaller municipalities.

Considering the whole sample, column 1 does not show any significant effect of broadband quality on income. This result holds even after regrouping the localities in different categories based on their city size. At one exception, the estimation results highlighta negative effect of broadband quality on income in localities located in smaller cities (rank 1). The difference of median income in localities having broadband speed between 5 Mbit/s and 100 Mbit/s is of about 2000 Swedish crowns (about 200 euro) lower than in other localities of rank 1 without broadband.

Table 4: Impact of broadband quality on income in localities characterized by a low proportion of highly educated inhabitants.

	whole sample	rank 1	rank 2	rank 3	rank 4	rank 5
speed: 0.256-5						
speed: 5-10		-2,004.22**				
speed: 10-30		-1,869.95**				
speed: 30-50		-2,066.12**				
speed: 50-100		-2,376.36**				
speed: 100+						
Observations	15,730,879	1,762,609	2,607,265	4,092,423	1,788,165	4,531,405
region	Yes	Yes	Yes	Yes	Yes	Yes
year	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.803	0.428	0.780	0.932	0.964	0.997

Robust standard errors clustered at the DeSo level: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$
rank 1: pop $\leq$ 18,937; rank 2: pop [19,938 - 44,813]; rank 3: pop [44,814 - 132,536];
rank 4: pop [132,537 - 354,349]; rank 5: pop $>$ 354,349.
A blank case means no significant effect.

Overall, for both "high-skill" and "low-skill" groups, the results, displayed in Annex B, show that the median income is more likely to be higher in more populated localities as well as in localities with a lower unemployment rate. However, localities having a higher proportion of inhabitants born outside Scandinavia or outside the EU are more likely to have a lower median income.

7.2 Impacts of Broadband Quality on Unemployment

The exhaustive estimation results are displayed in Annex B in tables 15 to 17.

Similarly to the previous estimations for income and at one exception, table 5 do not reveal any significant effect of broadband quality on the unemployment rate. Localities belonging to a municipality of rank 2 (with a population comprised between approximately 20,000 and 45,000 inhabitants) benefits positively of higher download speeds. In these localities, broadband quality has a positive impact on unemployment reduction: higher is the download speed, more likely it is to have a lower unemployment rate. Nonetheless, the positive effect of broadband quality is not linear. While the unemployment rate is about 1.2 percentage points lower in localities having lower broadband speed, between 256 Kbit/s and 5 Mbit/s, it is 2 to 2.5 percentage lowers in localities having higher download speeds (from 5 Mbit/s to 100 Mbit/s). However, there is no significant effect of broadband speeds over 100 Mbit/s on unemployment reduction.

Table 5: Impact of broadband quality on the unemployment rate.

	whole sample	rank 1	rank 2	rank 3	rank 4	rank 5
speed: 0.256-5			-1.22**			
speed: 5-10			-2.24**			
speed: 10-30			-2.02**			
speed: 30-50			-1.68*			
speed: 50-100			-2.47**			
speed: 100+						
Observations	31,472,261	3,525,312	5,214,433	8,125,057	3,542,393	11,065,066
Region	Yes	Yes	Yes	Yes	Yes	Yes
Year	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.862	0.753	0.875	0.941	0.912	0.993

Robust standard errors clustered at the DeSo level: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$
rank 1: pop $\leq$ 18,937; rank 2: pop [19,938 - 44,813]; rank 3: pop [44,814 - 132,536];
rank 4: pop [132,537 - 354,349].
A blank case means no significant effect.

Overall, the results, displayed in table 15, highlight a positive effect of the size of the municipal population and of the median income on unemployment reduction. However, and in the same way as for the previous estimations, the proportion of inhabitants born outside Scandinavia or outside the EU has a negative impact on the unemployment rate. Having a look at the whole sample, we also observe a negative impact of population density. However, when the localities are divided in different categories in function of their city size, we no longer observe any significant effect of population density.

In addition, the results highlight a negative effect of the local population on the unemployment rate: more populated is a locality, more likely it is to have a higher unemployment rate. However, after distinguishing between the different city sizes, we observe that this negative effect only holds for localities belonging to a small or medium-small municipality (ranks 1 and 2). As previously, the models predict a positive effect of educational attainment on unemployment reduction.

High-skilled Localities

The second part of the results concerns localities characterized by a high proportion of highly educated inhabitants (superior to the median). Overall, the model predicts an increase in the unemployment rate of high-skilled workers in areas with better broadband quality. However, after distinguishing between the city size, the model highlights a complementary effect between broadband quality and high-skill jobs in smaller and in bigger municipalities.

More precisely, the first column of table 6 highlights a non-linear effect of broadband speed on the unemployment rate. Unlike what could have been expected, the results show only a positive effect on unemployment reduction for low-speed broadband. As such, we find an overall negative effect of broadband quality on the unemployment rate. In localities with basic broadband (under 5 Mbit/s), the unemployment rate is 0.77 percentage points lower than in localities without broadband.

On the contrary, localities with higher broadband quality are more likely to experience a higher unemployment rate of about 1 to 2.75 percentage points higher than in localities without broadband. This result is in line with the negative impact of broadband quality on income we found in areas with a high proportion of highly educated inhabitants. An explanation could be that a new substitution effect between certain types of high-skill jobs and new ICT technologies is appearing. As highlighted by Brynjolfsson et al. (2011) and Frey et al. (2017), the progress made in machine learning and artificial intelligent as well as the availability of big data has led to the development of more sophisticated programs in all kind of sectors using data. For example, one of them is the bank and insurance sector. The implementation of new applications for e-medicine has increased the use of distance monitoring and diagnose techniques enabling doctors to help more patient in a lower time frame. The considerable improvement made in smart systems enables to substitute for some cognitive (routine and non-routine) tasks realized by high-skilled workers.

After taking into account the city size, we find that broadband quality has heterogeneous effects on unemployment. Columns 2 and 5 show that localities located in smaller cities, with less than 18,937 inhabitants, and localities located in bigger cities of rank 4, benefit positively from a higher broadband quality. Higher is the download speed, lower is the unemployment rate.

As regards the localities located in smaller cities (rank 1), the results highlight an increasing positive effect of broadband quality on unemployment reduction. In localities with basic broadband (under 5 Mbit/s), the unemployment rate is 1.20 percentage points lower than in localities of rank 1 without broadband, while in localities with higher broadband speed (over 5 Mbit/s and especially over 100 Mbit/s), the unemployment rate is approximately 2 to 2.2 percentage points lower than in localities without broadband. These results are in line with Atasoy (2013), who highlighted the existence of a positive association between broadband and employment especially in rural areas along with a complementary effect between broadband and education.

With respect to bigger municipalities (rank 4), we observe only a significant effect of broadband quality on unemployment reduction in localities with basic broadband and in localities with high-broadband speed broadband over 50 Mbit/s. In these localities, the unemployment rate is approximately 0.1 percentage point lower than in the localities without broadband. The positive effect of broadband quality is however lower in areas with ultra-fast broadband, download speeds over 100 Mbit/s, which experienced an unemployment rate of about 0.04 percentage point lower than the other localities of the same group which don't have broadband.

In addition, the results highlight that localities with a higher proportion of highly educated inhabitants located in medium-sized municipalities (ranks 2 and 3) do not experience any effect of broadband quality on unemployment reduction. There is no significant difference in the unemployment rate in localities without broadband or in localities with high-speed broadband.

Table 6: Impact of broadband quality on the unemployment rate in localities characterized by a high proportion of highly educated inhabitants.

	whole sample	rank 1	rank 2	rank 3	rank 4
speed: 0.256-5	-0.77***	-1.20*			-0.11*
speed: 5-10		-1.84**			
speed: 10-30	0.97**	-1.92**			
speed: 30-50	1.63***	-2.01*			
speed: 50-100	1.56**	-2.22*			-0.10**
speed: 100+	2.75***				-0.04*
Observations	15,741,382	1,762,710	2,607,396	4,032,640	1,754,337
region	Yes	Yes	Yes	Yes	Yes
year	Yes	Yes	Yes	Yes	Yes
Observations	15,741,382	1,762,710	2,607,396	4,032,640	1,754,337
R-squared	0.889	0.775	0.761	0.767	0.994

Robust standard errors clustered at the DeSo level: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$
rank 1: pop $\leq$ 18,937; rank 2: pop [19,938 - 44,813]; rank 3: pop [44,814 - 132,536];
rank 4: pop [132,537 - 354,349].
A blank case means no significant effect.

Low-skilled Localities

The third part of the results concerns localities characterized by a low proportion of highly educated inhabitants (inferior to the median). All in all, the model predicts a complementary effect between broadband quality and low-skilled jobs. However, this result holds only for medium-sized municipalities. A substitution effect is highlighted between better broadband quality and low-skill jobs in smaller municipalities.

More specifically, it stems from the results that, in general, localities which experience higher download speeds are more likely to have a lower unemployment rate. Except from localities with ultra-fast broadband, download speeds over 100 Mbit/s, where the results do not show any significant effect. Localities with broadband have on average an unemployment rate which is between 2 and 4 percentage points lower than in localities without broadband. This result confirms the job polarization effect highlighted by Autor et al. (2013). As broadband acts as a substitute to low-skilled workers to perform routine tasks, they reallocate into the service sector. A sector which is expected to benefit the most from ICT technologies (Hasbi (2020)).

Potentially, the absence of significant effect on income found earlier could also result from the fact that these new jobs created in the service sector are mainly low-paid jobs.

After distinguishing between the city size, the results show that localities located in smaller cities (of rank 1) tend to have a higher unemployment rate in areas with better broadband quality. This substitution effect had already been highlighted in the literature, especially by Akerman et al. (2015).

Similarly to the positive effect found for the whole sample, the results highlight a positive effect of broadband speed on unemployment reduction in localities located in a medium-sized city, but only for broadband speeds under 30 Mbit/s. Therefore, we do not observe any positive effect of high-speed or very high-speed broadband on unemployment reduction in these localities.

Localities located in a medium-sized city of rank 2 and having broadband speed over 5 Mbit/s and over 10 Mbit/s are more likely to have a lower unemployment rate than similar localities of rank 2 having no broadband. The difference in the unemployment rate is of about 2.4 and 1.8 percentage points respectively. The results also highlight a positive effect of basic broadband (under 5 Mbit/s) on unemployment reduction in medium-sized cities of ranks 3 and 4. The unemployment rate is more likely to be lower by roughly 2 percentage points in these localities compared to localities of the same category without broadband. Localities of rank 4 located in areas with broadband speed between 5 Mbit/s and 10 Mbit/s are also more likely to encounter a lower unemployment rate of about 2.3 percentage points. However, there is no significant effect of broadband quality on the unemployment rate of localities located in the largest cities.

Table 7: Impact of broadband quality on the unemployment rate in localities characterized by a low proportion of highly educated inhabitants.

	whole sample	rank 1	rank 2	rank 3	rank 4	rank 5
speed: 0.256-5	-2.19**	2.15**		-1.73**	-2.13**	
speed: 5-10	-2.42**		-2.36**		-2.38*	
speed: 10-30	-3.07**	1.64*	-1.83*			
speed: 30-50	-3.76**	2.50**				
speed: 50-100	-3.78**					
speed: 100+		5.35***				
Observations	15,730,879	1,762,602	2,607,037	4,092,417	1,788,056	4,531,405
region	Yes	Yes	Yes	Yes	Yes	Yes
year	Yes	Yes	Yes	Yes	Yes	Yes
Observations	15,730,879	1,762,602	2,607,037	4,092,417	1,788,056	4,531,405
R-squared	0.830	0.667	0.880	0.942	0.883	0.998

Robust standard errors clustered at the DeSo level: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$
rank 1: pop $\leq$ 18,937; rank 2: pop [19,938 - 44,813]; rank 3: pop [44,814 - 132,536];
rank 4: pop [132,537 - 354,349]; rank 5: pop > 354,349.
A blank case means no significant effect.

Overall, the results show, for both the “high-skill” and “low-skill” groups, that the unemployment rate is more likely to be higher in more populated localities. However, larger is the municipal population, more likely it is to have a lower unemployment rate. In the same way, localities with a higher median income are more likely to experience a lower unemployment rate. Similarly, to the results for the median income, localities located in a city of rank 2 having a higher proportion of inhabitants born outside Europe are more likely to encounter a higher unemployment rate.

8 Conclusion

Based on a unique and rich dataset, provided by the Swedish Internet Foundation, we assess whether broadband quality has an impact on income and unemployment reduction. We exploit micro-level cross-sectional data covering approximately 700 localities over 9 years, from 2009 to 2017. The results do not show any significant impact of broadband quality on either the median income or the unemployment rate. However, within-group analyses highlight heterogeneous effects across localities depending on both the education level of the local population and the municipality size. On average, broadband quality is shown to have an effect for download speeds comprised between 10 Mbit/s and 100 Mbit/s. The highest effects being encountered for speeds between 30 Mbit/s and 100 Mbit/s with some variations depending on the type of localities. Download speeds are reflecting the real download speed experienced by the users and not the theoretical download speed advertised by the operators.

The results underline a clear distinction between localities having a high and a low proportion of college graduates. Broadband quality is predicted to have a detrimental effect on both the median income and the unemployment rate in localities with highly educated inhabitants. Whereas, it has no significant effect on the median income and a positive effect on unemployment reduction in localities with a lower proportion of highly educated inhabitants.

Interestingly, this result provides some evidence of the existence of a substitution effect between new ICT technologies and more complex tasks performed by high-skilled workforce. The evolution of ICT technologies towards more intelligent systems capable of performing more complicated analytic tasks leads to a second wave of substitution to the detriment of highly educated workers. Therefore, the results are supporting the analyses from Brynjolfsson et al. (2011) and Frey et al. (2017), which show that the progress realized in digital technologies, especially in machine learning and AI combined with the increasing availability of big data, has led to computerize cognitive routine and non-routine tasks (that are usually performed by high-skilled workers).

After distinguishing between the different municipality sizes, the results tend to confirm the existence of a substitution effect between new broadband technologies and low-skill jobs but only in localities located in smaller municipalities. In medium-sized municipalities, the results tend to confirm the existence of a job polarization effect. As in a process of destruction creation, low-skilled workers, whose routine tasks have been first automated are now reallocating to the tertiary sector, where new jobs have been created. In addition, the model predicts that broadband quality has a complementary effect with high-skill jobs in smaller municipalities and to a lower extent in bigger municipalities.

With this report, we show that the relation between broadband quality and income or unemployment is not straightforward but rather is based on complex mechanisms. Both positive and negative effects are encountered. In accordance with our results, broadband quality can be seen as a tool to increase digital inclusion and reduce digital divide between people and territories, with a positive effect on unemployment reduction in medium-sized municipalities, where low-skilled jobs are predominant and in smaller municipalities, where high-skill jobs are predominant. In future research, when more detailed information becomes available on mobile data, it may become possible to estimate to which extent mobile broadband complement the effect of fixed broadband. Besides, it may also be interesting to compare how broadband quality affects company creation and entrepreneurship, especially in rural areas.

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Appendix A: Representativeness of the sample dataset and Descriptive Statistics

Table 8: Summary statistics of municipalities characteristics depending on the presence of a very high-speed broadband network for 2007-2017.

Variable	Obs	Mean	Std. Dev.	Min	Max
Whole dataset					
download	100,361,834	33.23089	65.96432	0	8161.384
upload	100,361,834	16.48973	49.47689	0	1929.298
latency	100,361,834	46.23508	163.6344	0	170655
pop_deso	100,361,834	1712.266	382.3808	346	3072
dens_deso	100,361,834	4954.929	5431.137	.1	65600
pop_municipality	100,361,834	353725.3	363618.7	974	932630
perc_sup	100,361,834	45.68388	16.15105	9.885057	91.75947
median income	100,361,834	257584.4	62173.22	1060	549496
perc_med_inc	100,361,834	47.43201	7.003945	4.074585	71.32743
perc_low_inc	100,361,834	25.0947	11.59378	4.938272	95.64917
perc_high_inc	100,361,834	27.47329	11.79748	.2762431	72.22222
unemployment 18-24	100,361,834	15.16282	14.0131	0	100
unemployment 18-64	100,361,834	76.22385	69.30409	3	458
born in SE	100,361,834	1363.247	287.7859	176	2804
born in Northern Europ	100,361,834	46.22218	26.65154	0	772
born EU	100,361,834	58.22672	33.59497	0	525
born international	100,361,834	244.5703	277.7754	3	1440
Sample dataset					
Variable	Obs	Mean	Std. Dev.	Min	Max
download	23,328,045	33.21822	66.01512	0	3750.311
upload	23,328,045	16.50191	49.42707	0	1891.674
latency	23,328,045	46.12913	162.8382	0	63495
pop_deso	23,328,045	1711.518	382.006	551	2993
dens_deso	23,328,045	4963.939	5434.482	.1	45050
pop_municipality	23,328,045	354349	363810.4	974	932630
perc_sup	23,328,045	45.71177	16.15994	9.885057	89.06089
median income	31,475,068	47.83512	7.097901	15.3481	71.3274
perc_med_inc	23,328,045	257621.8	62207.43	13046	439797
perc_low_inc	23,328,045	25.09577	11.59842	8.197989	81.30272
perc_high_inc	23,328,045	27.48434	11.8005	1.874414	60.8662
unemployment 18-24	23,328,045	15.15269	14.01278	0	81
unemployment 18-64	23,328,045	76.20619	69.34793	3	451
born in SE	23,328,045	1362.666	287.4906	392	2492
born in Northern Europe	23,328,045	46.20187	26.59538	4	772
born EU	23,328,045	58.23239	33.60254	0	525

Table 9a: Summary statistics of broadband speed by years: all year and from 2010 to 2013.

Whole dataset				Sample dataset			
All years							
	download	upload	latency		download	upload	latency
mean	33.22212	16.5019	46.13684	mean	33.21775	16.50142	46.1285
p25	4.602	.847	9	p25	4.602	.847	9
p50	11.802	3.018	21	p50	11.801	3.017	21
p75	38.046	11.90835	41	p75	38.04525	11.90809	41
iqr	33.444	11.06135	32	iqr	33.44325	11.06109	32
2010							
	download	upload	latency		download	upload	latency
mean	15.54365	5.837233	66.37854	mean	15.46758	5.796616	66.3235
p25	2.22	.424	10	p25	2.216	.426	10
p50	6.906	.865	24	p50	6.901	.865	24
p75	15.301	4.379	61	p75	15.221	4.288	61
iqr	13.081	3.955	51	iqr	13.005	3.862	51
2011							
	download	upload	latency		download	upload	latency
mean	17.98695	6.458129	65.72102	mean	18.07544	6.474116	65.59982
p25	2.446	.597	10	p25	2.478	.602	10
p50	6.893	.96	26	p50	6.913	.961	26
p75	16.884	7.016	73	p75	17.008	7.115	73
iqr	14.438	6.419	63	iqr	14.53	6.513	63
2012							
	download	upload	latency		download	upload	latency
mean	17.67088	6.614338	68.80112	mean	17.72645	6.637543	68.63141
p25	2.476	.692	11	p25	2.484	.694	10
p50	6.762	1.079	32	p50	6.776	1.081	32
p75	16.187	6.449	76	p75	16.277	6.629	76
iqr	13.711	5.757	65	iqr	13.793	5.935	66
2013							
	download	upload	latency		download	upload	latency
mean	17.67088	6.614338	68.80112	mean	21.14339	8.745704	57.32525
p25	2.476	.692	11	p25	3.541	.823	12
p50	6.762	1.079	32	p50	8.646	1.691	29
p75	16.187	6.449	76	p75	22.467	9.542	61
iqr	13.711	5.757	65	iqr	18.926	8.719	49

Table 9b: Summary statistics of broadband speed by years: from 2014 to 2017.

Whole dataset				Sample dataset			
2014							
	download	upload	latency		download	upload	latency
mean	21.17917	8.775536	57.57728	mean	30.23776	14.35815	43.37939
p25	3.548	.822	12	p25	5.999	.94	10
p50	8.689	1.688	28	p50	13.497	5.106	23
p75	22.487	9.539	60	p75	37.549	11.603	38
iqr	18.939	8.717	48	iqr	31.55	10.663	28
2015							
	download	upload	latency		download	upload	latency
mean	30.33757	14.31322	43.02006	mean	44.59054	22.17102	26.99246
p25	6.014	.935	10	p25	7.289	1.097	7
p50	13.535	5.029	23	p50	19.57	9.774	15
p75	37.876	11.605	38	p75	58.214	14.975	29
iqr	31.862	10.67	28	iqr	50.925	13.878	22
2016							
	download	upload	latency		download	upload	latency
mean	49.47903	26.71417	26.99776	mean	49.43423	26.79826	26.91774
p25	7.906	1.954	8	p25	7.886	1.949	8
p50	21.256	10.388	16	p50	21.134	10.387	16
p75	63.513	19.786	32	p75	63.261	19.805	32
iqr	55.607	17.832	24	iqr	55.375	17.856	24
2017							
	download	upload	latency		download	upload	latency
mean	59.81593	35.14223	25.3606	mean	59.7599	35.10861	25.29899
p25	9.442	2.931808	7	p25	9.345	2.924	8
p50	26.548	11.177	15	p50	26.30617	11.177	15
p75	81.713	38.43973	31	p75	81.3578	38.658	31
iqr	72.271	35.50792	24	iqr	72.0128	35.734	23

Table 10: Summary statistics of broadband speed by week.

Whole dataset				Sample dataset			
week 1							
	download	upload	latency		download	upload	latency
mean	33.22212	16.5019	46.13684	mean	33.27197	16.37436	46.07875
p25	4.602	.847	9	p25	4.605	.848	9
p50	11.802	3.018	21	p50	11.857	3.078	21
p75	38.046	11.90835	41	p75	38.431	11.905	41
iqr	33.444	11.06135	32	iqr	33.826	11.057	32
week 2							
	download	upload	latency		download	upload	latency
mean	33.22212	16.5019	46.13684	mean	33.21775	16.50142	46.12854
p25	4.602	.847	9	p25	4.602	.847	9
p50	11.802	3.018	21	p50	11.801	3.017	21
p75	38.046	11.90835	41	p75	38.04525	11.90809	41
iqr	33.444	11.06135	32	iqr	33.44325	11.06109	32
week 3							
	download	upload	latency		download	upload	latency
mean	33.22212	16.5019	46.13684	mean	33.25254	16.57967	46.25885
p25	4.602	.847	9	p25	4.611	.848	9
p50	11.802	3.018	21	p50	11.82479	2.999	22
p75	38.046	11.90835	41	p75	38.087	11.907	42
iqr	33.444	11.06135	32	iqr	33.476	11.059	33
week 4							
	download	upload	latency		download	upload	latency
mean	33.22212	16.5019	46.13684	mean	33.19263	16.50193	46.42016
p25	4.602	.847	9	p25	4.596	.845	10
p50	11.802	3.018	21	p50	11.77885	2.924	22
p75	38.046	11.90835	41	p75	37.992	11.904	42
iqr	33.444	11.06135	32	iqr	33.396	11.059	32

Appendix B: Estimation Results

Table 11: Number of cities and DeSo per population's group and per education level.

	rank 1	rank 2	rank 3	rank 4	rank 5	Average
Median % sup	25.98	33.54	41.94	59.37	60.97	42.79
City	114	65	76	51	8	290
DeSo	370	316	578	686	226	2,212
City if % sup $>$ median	79	36	47	19	7	114
City if % sup $\leq$ median	106	62	73	51	8	282
DeSo if % sup $>$ median	156	77	108	55	46	608
DeSo if % sup $\leq$ median	280	262	500	639	185	1,702

Table 12: Impact of broadband quality on median income.

	whole sample	rank 1	rank 2	rank 3	rank 4	rank 5
speed: 0.256-5	411.5163	-304.0844	-56.6037	-90.1084	14.8148	77.9530
	(316.520)	(619.869)	(397.287)	(602.946)	(258.670)	(56.062)
speed: 5-10	156.3506	-792.8776	-770.3026	-442.3586	-211.7337	-10.2835
	(394.350)	(726.772)	(681.931)	(741.631)	(456.714)	(18.317)
speed: 10-30	-256.1510	-957.1841	-685.5942	-636.6997	-244.6934	-37.6368
	(450.824)	(821.905)	(725.739)	(752.516)	(473.935)	(39.576)
speed: 30-50	-610.2642	-680.7421	220.4261	-883.3265	-394.6393	26.8149
	(546.587)	(936.942)	(860.219)	(790.054)	(532.606)	(38.068)
speed: 50-100	-1,040.9421	-901.6196	-1,021.1324	-915.4874	-618.9035	16.1642
	(672.973)	(1,064.695)	(1,116.811)	(833.744)	(574.922)	(46.082)
speed: 100+	-1,114.5859	416.4201	-1,489.1163	-879.6501	-836.8273	55.0201
	(920.335)	(1,148.205)	(1,310.472)	(1,065.236)	(587.069)	(53.377)
pop DeSo	47,901.6947***	15,859.7541**	26,802.9632***	31,311.9106*	84,373.1269***	63,638.1017
	(10,727.441)	(6,566.105)	(10,245.461)	(18,629.598)	(6,797.906)	(55,968.269)
pop city	2,570.8651					
	(1,997.205)					
density DeSo	-1.9271***	-5.6581	-8.1979***	-1.5114	-3.3037***	-10.6175*
	(0.639)	(3.670)	(3.065)	(2.467)	(0.274)	(5.034)
uni-diploma	1,338.4900***	1,899.0594***	2,082.3335***	722.3785**	2,301.1031***	1,005.7454***
	(335.675)	(227.215)	(211.494)	(350.652)	(192.070)	(262.285)
unemployment	-107.0828	-261.9774***	-375.6997***	-94.1226	-144.9663***	-142.9946
	(90.887)	(44.530)	(65.471)	(118.305)	(41.385)	(138.133)
born international	-107.2567***	-22.7169	13.6906	-133.8349***	-100.9737***	-50.4183*
	(18.677)	(18.252)	(20.706)	(39.678)	(13.744)	(25.065)
New company	-0.0164	-14.9843	-0.8062	-0.7459*	-0.0715	0.0001
	(0.019)	(12.002)	(1.712)	(0.401)	(0.097)	(0.001)
Constant	-141499.7241*	111,241.6567**	16,540.9486	31,492.4062	-450827.6639***	-138416.3109
	(85,612.334)	(48,255.208)	(76,351.250)	(138,761.930)	(48,675.539)	(392,357.622)
Observations	31,472,261	3,525,546	5,214,661	8,125,111	3,542,502	11,065,066
R-squared	0.898	0.691	0.837	0.908	0.986	0.996
Region	Yes	Yes	Yes	Yes	Yes	Yes
Year	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.898	0.691	0.837	0.908	0.986	0.996

Robust standard errors clustered at the municipal level in parentheses: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table 13: Impact of broadband quality and median income in localities characterized by a high proportion of highly educated inhabitants.

	whole sample	rank 1	rank 2	rank 3	rank 4
speed: 0.256-5	-78.1020	-16.6967	598.6916	-348.1468	138.1473*
	(106.533)	(561.137)	(649.634)	(300.130)	(65.729)
speed: 5-10	-157.4994	20.8733	1,922.0346**	-979.4983*	49.7325
	(189.906)	(868.502)	(925.394)	(520.814)	(113.257)
speed: 10-30	-282.8802	-23.8084	2,129.6457**	-1,016.1149**	106.7710
	(186.723)	(915.855)	(851.966)	(471.177)	(105.254)
speed: 30-50	-430.1726*	250.1690	3,231.2583***	-946.0156**	4.4746
	(236.152)	(1,081.631)	(1,003.850)	(474.865)	(112.025)
speed: 50-100	-611.2652**	238.3583	2,975.8938***	-1,165.5437**	45.8363
	(296.574)	(1,239.489)	(1,141.088)	(506.809)	(137.625)
speed: 100+	-1,060.5676**	1,534.5187	1,535.2564	-1,282.7303**	42.4337
	(469.112)	(1,349.205)	(1,540.500)	(549.637)	(194.899)
pop DeSo	58,518.2753***	12,473.2176	65,190.7891***	8,026.9277	53,666.9435
	(14,022.196)	(9,280.981)	(13,827.837)	(13,486.318)	(42,706.391)
pop city	-307.9821				
	(2,585.634)				
density DeSo	0.2242	-4.9023	-0.7125	-15.7047***	-1.6621
	(0.895)	(5.157)	(3.286)	(3.045)	(1.777)
unemployment	-423.1675***	-425.3130***	-921.2201***	-180.5190***	13.4023
	(122.161)	(84.382)	(155.891)	(63.893)	(19.534)
born international	-270.8392***	-28.0224	-132.0222***	-135.8577**	-22.2644
	(81.984)	(30.417)	(46.040)	(67.672)	(30.408)
new company	-0.0099	-14.5347	4.2788	-0.3022***	0.0266***
	(0.006)	(10.012)	(3.819)	(0.115)	(0.007)
Constant	-93,958.4115	217,769.4429***	-146970.8836	307,315.8908***	-104055.4404
	(108,203.400)	(71,748.898)	(101,756.023)	(95,332.504)	(298,481.508)
Observations	15,741,382	1,762,937	2,607,396	4,032,688	1,754,337
Region	Yes	Yes	Yes	Yes	Yes
Year	Yes	Yes	Yes	Yes	Yes
R-squared	0.926	0.640	0.736	0.947	0.991

Robust standard errors clustered at the municipal level in parentheses: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table 14: Impact of broadband quality on median income in localities characterized by a low proportion of highly educated inhabitants.

	whole sample	rank 1	rank 2	rank 3	rank 4	rank 5
speed: 0.256-5	89.9779	-492.9019	201.3766	-296.6374	-519.0384	15.6353
	(340.336)	(643.834)	(431.842)	(542.203)	(531.156)	(58.730)
speed: 5-10	144.3706	-2,004.2190**	-300.7939	-205.6919	-709.7405	-16.5364
	(600.237)	(777.947)	(606.836)	(648.277)	(744.186)	(72.916)
speed: 10-30	-191.7403	-1,869.9508**	178.8568	-72.8848	-744.9701	-43.3308
	(665.372)	(815.065)	(647.031)	(676.610)	(756.887)	(82.219)
speed: 30-50	-72.8581	-2,066.1186**	696.9002	104.3450	-648.6724	-55.2515
	(790.835)	(1,004.068)	(783.296)	(776.748)	(880.379)	(93.461)
speed: 50-100	-258.9427	-2,376.3639**	286.8437	329.8651	-960.1438	-81.9661
	(960.195)	(1,156.990)	(983.705)	(911.747)	(880.271)	(108.616)
speed: 100+	-392.7696	-1,895.1839	-438.5032	-58.8647	-649.4401	-91.6618
	(1,183.899)	(1,328.512)	(1,147.023)	(967.311)	(1,020.640)	(116.917)
pop DeSo	60,571.3253***	26,244.0130***	30,094.1958***	64,743.0157***	113,583.8351***	32,417.7665
	(10,200.827)	(6,547.168)	(7,968.767)	(12,647.769)	(8,507.462)	(48,188.855)
pop city	2,811.6715					
	(1,979.567)					
density DeSo	2.6337	3.8206	-4.2586**	-0.8529	-1.1505***	-12.0610*
	(2.127)	(4.485)	(1.932)	(1.753)	(0.186)	(5.473)
unemployment	-191.5517***	-294.6137***	-284.1019***	-167.5270	-361.1752***	-192.9710
	(57.345)	(48.628)	(54.066)	(150.383)	(64.124)	(125.152)
born international	-119.3999***	-21.5005	-30.2837	-127.0145***	-125.9756***	-23.7738
	(17.302)	(16.619)	(20.178)	(42.589)	(19.359)	(24.617)
new company	-1.2161	-5.2476	-1.9524	-0.8264	-0.5702	-0.0015
	(0.777)	(10.658)	(1.248)	(1.175)	(0.415)	(0.001)
Constant	-218239.9772***	42,605.2662	32,152.4296	-203549.2551**	-539259.6983***	147,401.8919
	(66,589.286)	(46,848.946)	(58,995.074)	(91,547.821)	(62,386.099)	(322,589.049)
Observations	15,730,879	1,762,609	2,607,265	4,092,423	1,788,165	4,531,405
Region	Yes	Yes	Yes	Yes	Yes	Yes
Year	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.803	0.428	0.780	0.932	0.964	0.997

Robust standard errors clustered at the municipal level in parentheses: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table 15: Impact of broadband quality on the unemployment rate.

	whole sample	rank 1	rank 2	rank 3	rank 4	rank 5
speed: 0.256-5	-0.3014	0.3774	-1.2119**	-0.5854	0.4403	0.1912
	(0.430)	(0.737)	(0.538)	(0.425)	(0.415)	(0.115)
speed: 5-10	-0.3153	-0.4740	-2.2405**	0.1538	0.7161	0.2426
	(0.626)	(0.729)	(0.927)	(0.561)	(0.809)	(0.156)
speed: 10-30	-0.4927	-0.2267	-2.0152**	0.3826	1.1075	0.2543
	(0.727)	(0.765)	(0.942)	(0.607)	(0.847)	(0.171)
speed: 30-50	-0.7449	0.1223	-1.6836*	0.4334	1.0351	0.2955
	(0.776)	(0.879)	(0.969)	(0.830)	(0.988)	(0.195)
speed: 50-100	-0.6377	-0.4576	-2.4673**	0.2704	1.2325	0.2785
	(0.828)	(1.021)	(1.182)	(0.755)	(1.084)	(0.192)
speed: 100+	0.0767	1.5659	-1.2536	1.9229	1.5109	0.3019
	(0.768)	(1.295)	(1.287)	(1.790)	(1.118)	(0.213)
pop DeSo	30.9116***	45.9745***	40.2865***	14.7770	-50.5761*	-69.1971*
	(9.387)	(4.042)	(9.375)	(14.343)	(29.635)	(31.243)
pop city	-5.9900*					
	(3.217)					
density DeSo	0.0022***	0.0048	-0.0008	0.0016	0.0001	0.0086
	(0.001)	(0.004)	(0.002)	(0.003)	(0.001)	(0.005)
uni-diploma	-0.5768***	-0.8754***	0.0863	-0.5110**	-0.7156*	-1.8192***
	(0.159)	(0.178)	(0.246)	(0.198)	(0.362)	(0.550)
income	-66.4642**	-83.7008***	-144.5744***	-115.0271***	-18.2520	-114.5647**
	(31.764)	(13.836)	(35.971)	(35.278)	(28.204)	(40.994)
born international	0.1475***	0.1580***	0.1579***	0.1370***	0.1458***	0.0470**
	(0.028)	(0.014)	(0.026)	(0.039)	(0.026)	(0.017)
New company	0.0000	0.0009	0.0076***	-0.0007*	0.0001	0.0000
	(0.000)	(0.011)	(0.002)	(0.000)	(0.000)	(0.000)
Constant	725.5678*	754.1453***	1,523.8009***	1,358.1843***	631.9875**	2,022.4742***
	(381.230)	(174.623)	(411.973)	(408.880)	(282.464)	(316.957)
Observations	31,472,261	3,525,312	5,214,433	8,125,057	3,542,393	11,065,066
Region	Yes	Yes	Yes	Yes	Yes	Yes
Year	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.862	0.753	0.875	0.941	0.912	0.993

Robust standard errors clustered at the municipal level in parentheses: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table 16: Impact of broadband quality on unemployment rate in localities characterized by a high proportion of highly educated inhabitants.

	whole sample	rank 1	rank 2	rank 3	rank 4
speed: 0.256-5	-0.7712***	-1.2028*	-0.0361	0.1768	-0.1105*
	(0.282)	(0.662)	(0.227)	(0.281)	(0.056)
speed: 5-10	0.0476	-1.8359**	0.0086	0.4015	-0.0998
	(0.337)	(0.824)	(0.403)	(0.315)	(0.059)
speed: 10-30	0.9675**	-1.9246**	-0.0200	0.3924	-0.1185
	(0.451)	(0.894)	(0.412)	(0.312)	(0.070)
speed: 30-50	1.6294***	-2.0103*	-0.0267	0.5331	-0.0107
	(0.590)	(1.058)	(0.433)	(0.325)	(0.040)
speed: 50-100	1.5584**	-2.2223*	-0.0326	0.4344	-0.1015**
	(0.617)	(1.239)	(0.485)	(0.286)	(0.033)
speed: 100+	2.7542***	-1.9186	0.4771	0.8117	-0.0361*
	(0.915)	(1.335)	(0.497)	(0.530)	(0.019)
pop DeSo	21.4822***	34.1194***	32.0899***	31.9772***	5.9769
	(5.500)	(6.123)	(5.408)	(4.827)	(4.607)
pop city	-4.2948***				
	(1.427)				
density DeSo	0.0024***	0.0049	0.0044***	-0.0017	-0.0004**
	(0.000)	(0.005)	(0.002)	(0.002)	(0.000)
income	-82.3790***	-84.3120***	-80.5798***	-73.0775***	-27.1345***
	(12.096)	(13.303)	(10.259)	(19.541)	(8.325)
born international	-0.0286	0.1865***	0.0636**	-0.0082	0.0008
	(0.028)	(0.023)	(0.024)	(0.014)	(0.003)
new company	-0.0000	-0.0288*	-0.0006	-0.0000	-0.0000*
	(0.000)	(0.015)	(0.002)	(0.000)	(0.000)
Constant	955.0455***	809.2960***	794.1334***	726.5859***	320.4679**
	(126.606)	(178.248)	(119.809)	(259.127)	(131.681)
Observations	15,741,382	1,762,710	2,607,396	4,032,640	1,754,337
Region	Yes	Yes	Yes	Yes	Yes
Year	Yes	Yes	Yes	Yes	Yes
R-squared	0.889	0.775	0.761	0.767	0.994

Robust standard errors clustered at the municipal level in parentheses: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table 17: Impact of broadband quality on unemployment rate in localities characterized by a high proportion of highly educated inhabitants.

	whole sample	rank 1	rank 2	rank 3	rank 4	rank 5
speed: 0.256-5	-2.1883**	2.1482**	-0.8655	-1.7348**	-2.1318**	0.0194
	(0.876)	(0.898)	(0.621)	(0.827)	(0.889)	(0.036)
speed: 5-10	-2.4218**	1.0140	-2.3608**	-0.7840	-2.3771*	0.0438
	(1.204)	(0.863)	(1.011)	(0.913)	(1.299)	(0.063)
speed: 10-30	-3.0667**	1.6392*	-1.8323*	-0.4217	-2.1345	0.0763
	(1.374)	(0.888)	(1.081)	(0.816)	(1.397)	(0.086)
speed: 30-50	-3.7648**	2.4961**	-1.4115	-0.2696	-1.4861	0.1012
	(1.503)	(0.977)	(1.172)	(1.259)	(1.475)	(0.107)
speed: 50-100	-3.7801**	1.5927	-2.0118	0.1717	-1.1663	0.1336
	(1.641)	(1.182)	(1.612)	(1.148)	(1.594)	(0.134)
speed: 100+	-1.8287	5.3491***	-0.0628	4.0698	0.9222	0.0929
	(1.551)	(1.798)	(1.776)	(3.083)	(2.116)	(0.114)
pop DeSo	44.9541***	48.6849***	54.6011***	45.9460**	-62.7251	-23.3287**
	(11.472)	(4.820)	(15.357)	(22.922)	(40.393)	(9.828)
pop city	-15.1523***					
	(3.519)					
density DeSo	0.0098**	0.0065	-0.0008	0.0019	0.0006	0.0040**
	(0.005)	(0.005)	(0.002)	(0.003)	(0.001)	(0.002)
income	-110.2095***	-108.4533***	-222.6395***	-187.4785***	-36.3336	-195.7442***
	(28.763)	(20.110)	(46.747)	(40.267)	(36.563)	(22.222)
born international	0.1035***	0.1452***	0.1059***	0.0798**	0.1590***	0.0178
	(0.028)	(0.017)	(0.034)	(0.037)	(0.033)	(0.019)
new company	-0.0030	0.0198	0.0060*	-0.0034	-0.0019***	0.0000
	(0.002)	(0.017)	(0.003)	(0.002)	(0.001)	(0.000)
Constant	1,218.9544***	1,035.8938***	2,373.6784***	1,991.6354***	904.2652***	2,652.7263***
	(352.230)	(240.186)	(537.839)	(445.232)	(259.815)	(246.453)
Observations	15,730,879	1,762,602	2,607,037	4,092,417	1,788,056	4,531,405
Region	Yes	Yes	Yes	Yes	Yes	Yes
Year	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.830	0.667	0.880	0.942	0.883	0.998

Robust standard errors clustered at the municipal level in parentheses: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$